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The Hypothetical Learning Trajectory on Research in Mathematics Education Using Research-Based Learning

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Abstract. This study aims to create a learning trajectory on research in mathematics education using design research methodology to enhance research and academic writing skills for pre-service mathematics teachers. The fourteen pre-service mathematics teachers during 5 months period from one higher education institution in Tangerang – Indonesia was collected. The design research method was carried out in three phases: preliminary design phase, teaching experiments phase, and retrospective analysis phase. Initial data analysis of 14 pre-service teachers' research and academic writing skills was conducted in six stages and the learning trajectories on this topic was identified. The fourteen pre-service teachers were divided into 7 groups and research independently to produce seven scientific articles. The six articles were published in the proceedings of *Konferensi Nasional Matematika* (National Congress of Mathematics) XVII 2014 and one article was published in the Elemen Journal Vol. 1 No. 1.

Keywords: *Research and Academic Writing Skills, Research-Based Learning, Design Research.*

Several studies indicated that undergraduate students faced difficulties in writing thesis, affecting the length of their study (Bangun, Irmeilyana, & Andarini, 2011; Fathonah, Wahyuningsih, & Wahyuningsih, 2011; Firmansyah, 2014; Prahmana, 2014; Santosa, Wiyanarti, & Darmawan, 2009). In Indonesia, undergraduate students are required to write a thesis as part of their research training (*PERMEN No. 49 Tahun 2014*). The completion rate usually takes up 2 to 4 semesters. Limited knowledge of methodology, the capacity of research advi-

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sors, limited research training and experience in academic writing and low-involvement of students to resolve their problems were identified as main source of difficulties (Firmansyah, 2014; Fathonah, Wahyuningsih, & Wahyuningsih, 2011; Puspitasari, 2013). Difficulties in academic writing is also due to lack of motivation, anxiety, and language constraints (Rahmiati, 2014). Therefore, research and academic writing skills are accepted as important skills in the quality of learning of academic training.

Indonesian Directorate of Higher Education Institution to encourage more research and publications by students including undergraduate students issued a policy (*PERMEN No. 49 Tahun 2014*). Furthermore, the National Standard Qualification (Tim Penyusun KKNI Dikti, 2013) requires students to publish their research in a reputable national journal (acknowledged by KKNI level 6). On the other hand, some researchers have documented the success of research-based learning to enhance students' skills in conducting research (Widayati et al., 2010; Waris, 2009; Umar et al., 2011; Webb, Smith, & Worsfold, 2011; GIHE, 2008; University of Adelaide, 2009), but the greater part of them are still focused on the students who come from non-education department.

Willison & O'Regan (2007) developed six research skill indicators that are classified into 5 levels of research. Furthermore, Dowse and Howie (2013), conducted within the framework of design research, sought to design and develop an academic research writing intervention. Prahmana (2014) identified that the learning process at the university did not offer enough support for students to develop their academic writing skills. Therefore, this study aims to create a learning trajectory on research in mathematics education using design research methodology to enhance research and academic writing skills for pre-service mathematics teachers. Based on the problems mentioned, the success of the learning activities to improve pre-service teachers' skills is investigated in research question as follows, *"To what extent do the learning trajectory on research in mathematics education in assisting pre-service mathematics teachers to enhance their research and academic writing skills?"*

Research-Based Learning (RBL)

Boud & Feletti (1998) mention six principles which should guide the implementation of RBL, namely multiplicity, activeness, accommodation and adaptation, authenticity, articulation, and timelessness. Furthermore, Neo (2003) also mentions the six principles by using different terms, namely constructivism, contextual learning theory, discovery learning theory, information-process learning orientation, cooperative learning theory, and self-determination theory. RBL activity starts from identifying the problem, extracting knowledge and skills, solving the problem or application, and concluding with reflection (Farkhan, 2008). This is supported by Poonpan & Suwanmankha (2005) which states that RBL involves students in constructing knowledge with the five stage

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namely finding problems, formulating problems, collecting data, analyzing data, and making conclusions from the data and new learning. Therefore, it can be concluded that the RBL is a learning based on the philosophy of constructivism, which includes self-learning focused on the student, with the prior knowledge that is developing an authentic problem solving, then resolved through meaningful learning in the form of research (learning by doing), the results are communicated as dissemination or scientific publication.

The syntax of RBL developed by Universitas Gadjah Mada (Widayati et al., 2010) adopt the PBR strategy at the University of Griffith (GIHE, 2008) and the University of Melbourne (Baldwin, 2005). Additionally, the syntax of RBL was also developed by Program Studi Fisika Institut Teknologi Bandung (Waris, 2009). Based on that, the syntax in this research is more likely to use the syntax that was developed by the University of Griffith (GIHE, 2008) and the University of Melbourne (Baldwin, 2005), with modification focused on research in mathematics education.

Research Skills

Research skills are the skills to do research in order to find the truth by using systematic stages and producing correct and reliable data to answer a question or test a hypothesis (Waris, 2009; Webb, Smith, & Worsfold, 2011; Majelis Profesor Riset Lembaga Ilmu Pengetahuan Indonesia, 2007). Research activities, systematic investigation of a phenomenon, problems, issues, questions, and so forth, to increase knowledge and understanding, are the core activity in research-based universities (Widayati et al., 2010; Waris, 2009; Umar et al., 2011; GIHE, 2008; Baldwin, 2005). Therefore, research skills become the skill that must be possessed by students in conducting research. It becomes important to examine the skills developed because with the increasing complexity of society and the world of work, need a better understanding of the results of scientific research and research-based communications. In addition, research skills to be valuable as appropriate research methods can provide a way on how to get accurate and reliable information, so with competence skills possessed researching, students are expected to provide a view of "what could happen" and also skills to discover "what really happened", so that students have the skills necessary to establish awareness of themselves.

Primary Years Program (PYP) Curriculum Framework develops research skills indicators into eight indicators (International Baccalaureate, 2009). Furthermore, Willison & O'Regan (2007) developed six research skills indicators and subsequently developed by the University of Adelaide (2009) set out in the Handbook for Research Skills Development and Assessment in the Curriculum. Based on all these indicators, researcher summarize research skills indicators into six indicators. There are (1) Students are able to formulate

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research question, (2) Students are able to observe and find required information and relevant methodology, (3) Students are able to conduct the research, (4) Students are able to sort and describe the research data that has been collected, (5) Students are able to analyze research data to answer the research question and then interpret them, as well as making conclusion, (6) Students are able to communicate their research results, whether in the form of dissemination in scientific forums and scientific publications in the form of journal or proceedings.

Academic Writing Skills

Academic writing skills can be interpreted as the skill to produce a paper under standard rules and using a particular scientific method (Supriyadi, 2013; Rahmiati, 2014). Writing a scientific paper has several stages and procedures such as looking for ideas by reading, observing, conducting research, conducting experiments, finding the data, and supporting theory and further writing down the results (Rahmiati, 2014). Suparno (2012) provides general steps in writing a scientific article, namely developing the ideas, planning the text, developing paragraph, writing draft, and finalization. Furthermore, Supriyadi (2013) describes 13 stages in writing a good scientific paper. There are (1) understanding the nature of scientific paper; (2) understanding the difference between scientific paper and non-scientific paper; (3) identifying topics; (4) limiting the topic; (5) formulating the title of scientific paper; (6) formulating the problem of scientific paper; (7) formulating the thesis of scientific paper; (8) framing the scientific paper; (9) developing ideas and paragraphs groups; (10) quotation processing; (11) using the standard language in the scientific paper; (12) writing a list of references; and (13) editing the paper. In addition, scientific paper must also meet the rules of writing scientific language, such as the use of standard grammar, word choice, and the effectiveness of writing (Zulkarnain, 2012). All stages and requirements led to students having difficulty in writing a scientific papers (Yuniawan & Wardani, 2008; Sudiati & Nurhidayah, 2008; Ulfah et al., 2013). Therefore, it takes a special treatment at every stage by controlling every stage through certain indicators in order to produce the skills to write a good scientific paper.

The Hypothetical Learning Trajectory (HLT) in this study has several learning goals expected to be reached by the students. To reach the goals formulated, researcher designs a sequence of instructional learning for research in mathematics education to enhance research and academic writing skills (Figure 1).

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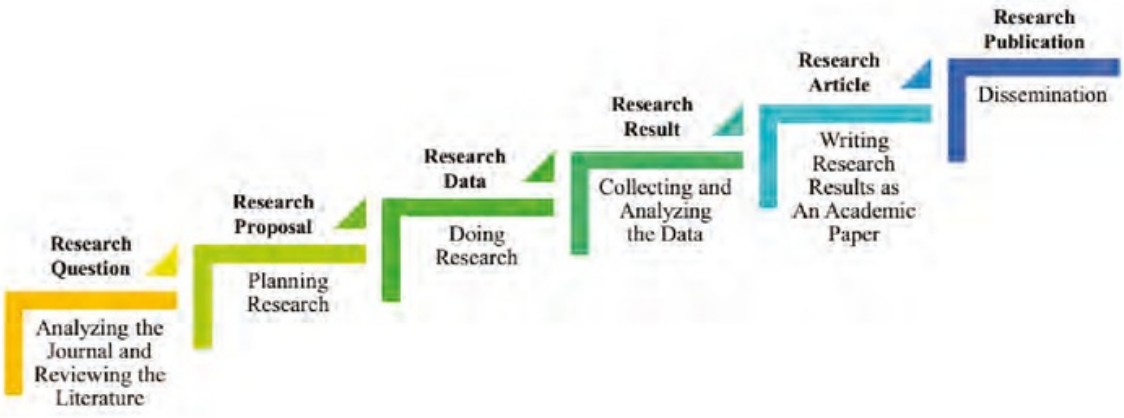

Fig. 1. *The Hypothetical Learning Trajectory on Research in Mathematics Education*

Method

This study uses a design research as research method, which is an appropriate way to answer the research questions and achieve the research objectives that start from preliminary design, teaching experiments, and retrospective analysis (Prahmana, 2013). Design research is a methodology that has five characteristics, namely interventionist nature, process oriented, reflective component, cyclic character, and theory oriented (Akker et al., 2006). Design research is a cyclical process of thought experiment and instruction experiments to implementation (Gravemeijer, 2004). There are two important aspects related to design research. They are the Hypothetical Learning Trajectory (HLT) and Local Instruction Theory (LIT). According to Freudenthal (in Gravemeijer and Eerde, 2009), students are given the opportunity to build and develop their ideas and thoughts when constructing mathematics. Teachers can select appropriate learning activities as a basis to stimulate students to think and act when constructing mathematics. Gravemeijer states that the HLT consists of three components, namely (1) the purpose of mathematics teaching for students, (2) learning activities, devices or media used in the learning process, and (3) a conjecture of understanding the process of learning how to learn and strategies students that arise and thrive when learning activities are done in class (Gravemeijer, 2004). The fourteen pre-service mathematics teachers during 5 months period from one higher education institution in Tangerang – Indonesia was collected. The design research method was carried out in three phases: preliminary design phase, teaching experiments phase, and retrospective analysis phase. Initial data analysis of 14 pre-service teachers' research and academic writing skills was conducted in six stages and the learning trajectories on this topic was identified. This study consists of three

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steps done repeatedly until the discovery of a new theory that a revision of the theory of learning is tested (Figure 2).

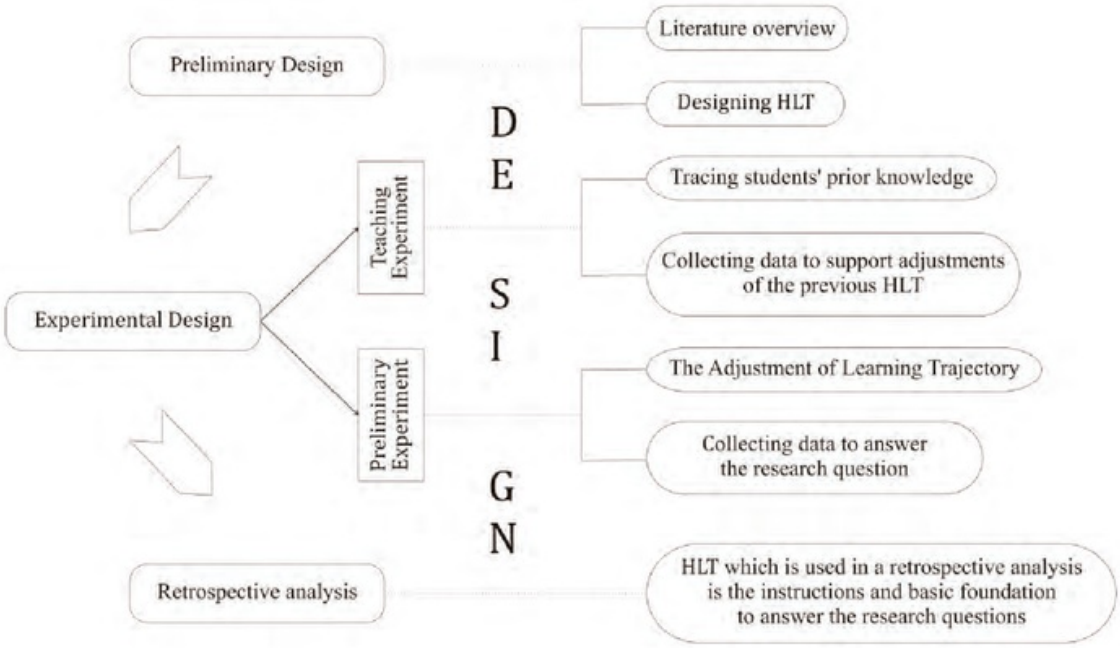

Fig. 2. *Phase of the Design Research (Prahmana, 2012)*

Results

The results of this study indicate that learning trajectory on research in mathematics education have a very important role in assisting pre-service mathematics teachers to enhance their research and academic writing skills. The learning activities start from (1) dividing 14 pre-service mathematics teacher into seven groups to do research independently, reviewing mathematics education journal, searching and observing the current problem issue in mathematics education, and making research question; (2) designing and doing research based on observation results to answer the research question; (3) collecting and analyzing the research data and also making the conclusion; (4) searching the conference event, submitting the research abstract, and attending also to this event; and the last, (5) writing full paper based on the research result and publishing that paper in proceedings or journal as a part of dissemination stage. Furthermore, students collect all research process portfolio and give them research and academic writing skills questionnaire as one of evaluation process in this learning activities. As a result, students were able to do research, write scientific paper, and publish it seen from the research results in the end of activities. There are seven scientific articles that published in the proceedings of *Konferensi Nasional Matematika XVII 2014* (six scientific paper) and the *Jurnal Elemen*

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Vol. 1 No. 1 (one scientific paper). For more detail, the researcher will discuss the results of the learning process on research in mathematics education, which is divided into three stages namely preliminary design, teaching experiments, and retrospective analysis.

Preliminary Design

At this stage, the literature study on research-based learning, research skill, and academic writing skill was conducted by researcher including develop learning design and skills indicators. Furthermore, researcher conducted observations in undergraduate student, designing hypothetical learning trajectory (HLT), as shown in Figure 1. A set of activities for learning research in mathematics education has been designed based learning trajectory and thinking process of students who hypothesized and also discussed about learning trajectory and all indicator with Prof. Dr. Darhim and Dr. Nancy Susiana as an expert validator. The instruction set of activities has been divided into six activities that have been completed in 10 meetings that has been discussed above.

Teaching Experiment

At this stage, the learning activities that have been designed in the preliminary design stage was tested by researcher. There are the student activity of dividing 14 pre-service mathematics teacher into seven groups to do research independently, reviewing mathematics education journal, searching and observing the current problem issue in mathematics education, and making the research question. Next, all groups design and research based on observation results to answer the research question. After that, they collect and analyze the research data and also making the conclusion. Furthermore, lecture and all groups were searching the conference event and submitting the research abstract to this event. Lastly, they written full paper guided by the lecture based on the research result and published that paper in proceedings or journal as a part of dissemination stage. To see the response of the students during the learning process, researcher give them research and academic writing skills questionnaire and also collect all research process portfolio as one of evaluation process in this learning activities.

Retrospective Analysis

As a result, all activities which have been designed can be used to answer the research question above. The fourteen pre-service teachers were divided into 7 groups and conducted research independently to produce seven scientific articles. The six articles

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were published in the proceedings of *Konferensi Nasional Matematika XVII 2014* and one article was published in the *Jurnal Elemen Vol. 1 No. 1*. For more details, the results of the learning process on research in mathematics education will be discussed. The activities are as follows:

Learning trajectory which has been designed in Figure 1 is the activity undertaken in this study to guide students doing research and writing scientific paper as a their research result by using research-based learning. So that, researcher designed an activity that make students review journal and find "hot" issue in mathematics education. This activities start from dividing all students into 7 groups and conduct research independently. The goal is that students are able to design learning trajectory for their research (Figure 3).

Fig. 3. *One of the student's learning design for her research*

Furthermore, all groups collected research data based on their research and analyzed that data and also made the conclusion. Next, they are looking for the conference and submitting their research abstract to this event as a part of dissemination of their research (Table 1).

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Table 1. **All research abstracts that have been submitted to *Konferensi Nasional Matematika***

TIM	Nama Mahasiswa	Judul Artikel Ilmiah
1	Dyah Indah Adrelia Venny Kurniawati	Pemahaman Konsep Pembelajaran Kelipatan Persekutuan Terkecil Menggunakan Permainan Tradisional Boom Angka Untuk Anak Kelas IV Sekolah Dasar
2	Olanda Dwi Sumintra Armianti	Pembelajaran Operasi Pengurangan Bilangan Bulat Melalui Permainan Tradisional Kelereng di Kelas III Sekolah Dasar
3	Nurochmah Novia Larosa	Penanaman Konsep Materi Operasi Pembagian Menggunakan Permainan Tradisional Bola Bekel di Kelas II Sekolah Dasar
4	Yuli Pinasthika Yuannisya Walimun	Pentingnya Pengaruh Permainan Tradisional Layang-layang Dalam Pembelajaran Phytagoras Di Kelas VIII Sekolah Menengah Pertama
5	Fadila Hasmita Oryza Zafivani	Pengunaan Permainan Tradisional "Icak-Icakan" Dalam Pemahaman Materi Persentase Laba Rugi Pada Siswa Dengan Gaya Belajar Cenderung Kinestetik
6	Ira Silviana Rahman Dwi Wulandari	Mathcan (Mathematics Dakocan) Sebagai Media Untuk Meningkatkan Kemampuan Berhitung Siswa Kelas I Sekolah Dasar
7	Sri Ratna Dewi Sari Juliana	Penggunaan Permainan Tradisional Yeye Dalam Pemahaman Konsep Operasi Perkalian Untuk Siswa Kelas III Sekolah Dasar

Next, full paper based on the research result and feedback from all participants in conference that had been seen their present was written by all groups and guided by their lecture.

Lastly, they submit that paper in proceedings or journal. As the result, students were able to publish the research results in the end of activities. There are six scientific articles that were published in the proceedings of *Konferensi Nasional Matematika XVII 2014* (Team 2-7) and one scientific paper in the *Jurnal Elemen Vol. 1 No. 1* (Team 1) as a product of this research (research and academic writing skills).

The retrospective analysis occurred in the first cycle showed that these pre-service teachers were on the level 1 and 2, based on research skill indicators developed by Willison and O'Regan (2007). Further research analysis will be needed to revise the HLT which will be then tested back in the next cycle (further research).

Discussion

This study creates a learning trajectory on research in mathematics education using design research methodology (Gravemeijer and Cobb, 2013) to enhance research and academic writing skills for pre-service mathematics teachers. Initial data analysis of 14 pre-service teachers' research and academic writing skills were conducted in six stages and the learning trajectories on this topic were identified. The fourteen pre-service teachers were divided into 7 groups and conducted research independently to produce seven scientific articles. The six articles were published in the proceedings of *Konferensi Nasional Matematika XVII 2014* and one article was published in the *Jurnal Elemen Vol. 1 No. 1.* The retrospective analysis occurred in the first cycle showed that these pre-service teachers were on the level 1 and 2, based on research skill indicators developed by Willison & O'Regan (2007). Further analysis will be needed to revise the HLT which will be then tested back in the next cycle.

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Appendix

English Transcript (Figure 3)

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English Transcript (Table 1)

Team	Students' Name	Title
1	Dyah Indah Adrelia Venny Kurniawati	Learning the concept of Lowest Common Multiple (LCM) using Indonesian Traditional Games "*Boom Angka*" in fourth grade
2	Olanda Dwi Sumintra Armianti	Learning subtraction operation using Indonesian Traditional Games "*Kelereng*" in third grade
3	Nurochmah Novia Larosa	Learning division operation using Indonesian Traditional Games "*Bola Bekel*" in second grade
4	Yuli Pinasthika Yuannisya Walimun	The importance of the influence of Indonesian Traditional Games "*Layang-Layang*" in learning Pythagorean Theorem Junior High School
5	Fadila Hasmita Oryza Zafivani	Learning percentage using Indonesian Traditional Games "*Icak-Icak*" for student with kinesthetic learning style
6	Ira Silviana Rahman Dwi Wulandari	Mathcan (Mathematics Dakocan) as a learning tool to improve the numeracy skills in first grade
7	Sri Ratna Dewi Sari Juliana	Learning multiplication operation using Indonesian Traditional Games "Yeye" in third grade

Hipotetinis mokymo(si) modelis matematiniame ugdyme taikant tyrimais grįstą mokymą(si)

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Summary

Tyrimai rodo, kad studentai, turėdami nepakankamai išsiugdytus mokslinių tyrimų ir akademinio rašymo gebėjimus, dažnai susiduria su baigiamųjų darbų rengimo problemomis universitetuose. Pažymėtina, kad universitetai taip pat skiria nepakankamą dėmesį studentų akademinio rašymo gebėjimams ugdyti. Šiame straipsnyje pristatomas mokymo(si) modelis matematiniame ugdyme taikant tyrimais grįstą mokymą(si). Toks modelis sudarytų sąlygas studentams, būsimiesiems matematikos mokytojams, tobulinti mokslinių tyrimų ir akademinio rašymo gebėjimus. Tyrime dalyvavo keturiolika būsimųjų matematikos mokytojų iš Indonezijos. Tyrimas atliktas trimis etapais: pradinis tyrimo projektavimo etapas, mokymų ir eksperimentų etapas ir retrospektyvinės analizės etapas. Tyrimo rezultatai atskleidė, kad sukurtas mokymosi modelis turi didžiulę įtaką būsimiesiems matematikos mokytojams tobulinant mokslinių tyrimų ir akademinio rašymo gebėjimus.

Esminiai žodžiai: *tyrimų ir akademinio rašymo gebėjimai, tyrimais grįstas mokymas(is), tyrimų projektavimas.*

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